

**PATENT APPLICATION**

**TWIN-T DUAL NOTCH FILTER**

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## TWIN-T DUAL NOTCH FILTER

### CROSS-REFERENCES TO RELATED APPLICATIONS

[01] NOT APPLICABLE

### STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[02] NOT APPLICABLE

### REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK.

[03] NOT APPLICABLE

### BACKGROUND OF THE INVENTION

[04] This invention relates to image and unwanted signal rejection in portable dual mode receiver circuits. The invention has particular application to cellular telephone technology wherein a single compact battery powered receiver must be able to operate on at least two disparate frequency bands with different channel spacing. In particular, the invention relates to problems associated with conversion and rejection of signals for digital cellular telephones operative in the AMP/PCS/GSM/EDGE bands (850 MHz, 900 MHz, 1900 MHz bands) which have 200 kHz channel spacing and in the IS136 band (~850 MHz band) which has 30 kHz channel spacing.

[05] There is a need to minimize avoidable components to save power and space in critical applications such as miniature portable cellular receiver circuit devices. The challenge is to provide rejection of unwanted signals and images at the input into the digital subsystem.

[06] Many signal conversion systems with passive low-pass filters of sufficiently steep rolloff to attenuate adjacent and next-adjacent channels or images are difficult to realize. The spacing of the channels or signals and images is such that energy is often well within the skirts of a typical rolloff characteristic of a passive low-pass filter.

[07] What is therefore needed is a filter circuit which provides adequate signal rejection at frequencies of interest and yet which is simple to realize and construct in the context of mass manufacturing.

[08] Active twin-T filters and passive twin-T filters are known. However, their use in combination or as alternatives in the same circuit is not.

## SUMMARY OF THE INVENTION

[09] According to the invention, a communication filter circuit useful in a dual-mode superheterodyne receiver comprises a cascade of an active twin-T filter and a passive twin-T filter section each defining sharp notches at the center of adjacent and of next adjacent channels, respectively, and specifically providing most attenuation at 60 kHz and at 90 kHz for operation with signals converted from frequencies in the 800-3000 MHz spectrum. Specifically in a circuit for detecting the ISM136 band which has 200 kHz channel spacing a passive twin-T circuit section is employed and in the GSM bands which have a 30 kHz channel spacing, an active twin-T circuit is used. Since communication is channelized and limited in bandwidth, an active/passive twin-T notch filter structure is effective for the intended spurious signal attenuation. In a circuit in which real and imaginary signal components are processed, active/passive twin-T filters are provided in each of four signal paths, namely I and -I, as well as Q and -Q.

[10] The invention will be better understood by reference to the following detailed description in connection with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

[11] Figure 1 is a block diagram of a circuit incorporating the invention.

[12] Figure 2 is a schematic diagram of a circuit implementation of a circuit according to the invention.

[13] Figure 3 is a circuit diagram of a combination of active and passive twin-T sections.

## DETAILED DESCRIPTION OF THE INVENTION

[14] Referring to Figure 1, there is shown a simplified diagram of a down-converting receiver 10 with a pair of dual twin-T notch filter sections 12, 14 to extract in-phase (I) and quadrature-phase (Q) components of a signal downconverted to baseband. RF energy received through an antenna 16 is amplified by amplifier 18 and mixed down to an intermediate frequency band (IF) at 135 MHz through a first mixer 20 which outputs the product of the RF signal and a mixer signal from a first stable signal source 22 at a frequency of the nominal RF frequency less the IF frequency (RF-135 MHz). The IF signal is processed through a surface acoustic wave (SAW) filter 24 to reject the image. The signal is then split

for I and Q processing and applied to respective second and third mixers 25, 26. The outputs (as indicated in the first spectrum graph A of Fig. 1) are each the products at baseband of the IF input and a second stable source 28 operative at 135 MHz. The first output is offset by 90 degrees as a consequence of a quadrature (+90 degree) phase shift introduced by a phase shifter 30. In each channel, an active first twin-T notch filter 32, 34 (as hereinafter described) introduces a null at the second adjacent channel position (60 kHz) (as indicated in the second spectrum graph B of Fig. 1). Similarly, in each channel, a passive second twin-T notch filter 36, 38 (as hereinafter described) introduces a null at the third adjacent channel position (90 kHz) (as indicated in the second spectrum graph B of Fig. 1). The outputs are the desired I and Q component signals which are then applied to respective analog to digital converters (not shown) for further processing as digital values. Further selectivity can be achieved with a digital finite impulse response (FIR) filter (not shown) to address adjacent channel interference.

[15] Figure 2 illustrates a specific dual mode receiver circuit 100 which incorporates dual active/passive twin T circuits 112, 114 when operating in its IS-136 mode and single passive notch filter section circuits 113, 115. The RF signal is processed in a commercially-available combination LNA/mixer chip 120 whose outputs are directed either through a first SAW filter 124 or a second SAW filter 125. The outputs are provided to a commercially-available quad demodulator chip 126 operative to downconvert and divide the source signals into baseband frequency I and Q components from the respective IF source frequencies. The I and Q components at the IS-136 band are processed through the dual twin-T filters 112, 114. The GSMK/EDGE signals, whose channel spacing does not require the sharp rolloff of signals, are processed through the passive notch filter networks 113, 115.

[16] As an example, the dual active/passive twin T circuit 114 and the lowpass filter 115 for the Q signal path are illustrated in Figure 3 for a specific embodiment. (The I signal path is identical, as can be seen from Figure 2). Each of the active sections is built around a conventional operational amplifier U7A and U7B. Active twin T sections comprise, in one-half of the differential set, series capacitors C24A, C24B split by a shunt resistor R 13C to the inverting input and series resistors R13A, R13B split by a shunt capacitor C24C to the inverting input are disposed at the respective inverting and non inverting inputs. In the feed-forward loop, a T-section is provided of series resistors R7C and R7D split by a shunt capacitor C16 to ground. The topology of the active twin-T circuit is called an active bootstrap configuration. It allows for enhanced Q as compared to other configurations. An

identical topology is provided for the differential side of the circuit. Specific component values are called out for a 60 kHz notch.

[17] The passive twin-T sections are used in a balanced configuration which comprises two parallel differential inputs 150, 152 each split into two paths according to the twin-T topology. For the first differential input 150, a first pair of series capacitors C14A, C14B are split by resistor R9 coupled to split a second pair of series capacitors C14C, C14D which are off of the second differential input 152. Similarly, for the first differential input 150, a first pair of series resistors R14A, R14B are split by capacitor C27 coupled to split a second pair of series resistors R14C, RC14D which are off of the second differential input 152. The first capacitor pair is shunted across by the first resistor pair to form a node of a first differential output 154. The second capacitor pair is shunted across by the second resistor pair to form a node of a second differential output 156. The resistance and capacitance values called out are suitable for a 90 kHz notch.

[18] The group delay of the active notch filter is less than that of the passive notch filter so that the slope of the active notch can be steeper without resulting in filter instability, thus accommodating wanted signals while suppressing unwanted signals at adjacent channels, particularly, second adjacent channels, in a system of closely spaced channels.

[19] The invention has been explained with reference to specific embodiments. Other embodiments will be evident to those of ordinary skill in the art. It is therefore not intended that this invention be limited, except as indicated by the appended claims.